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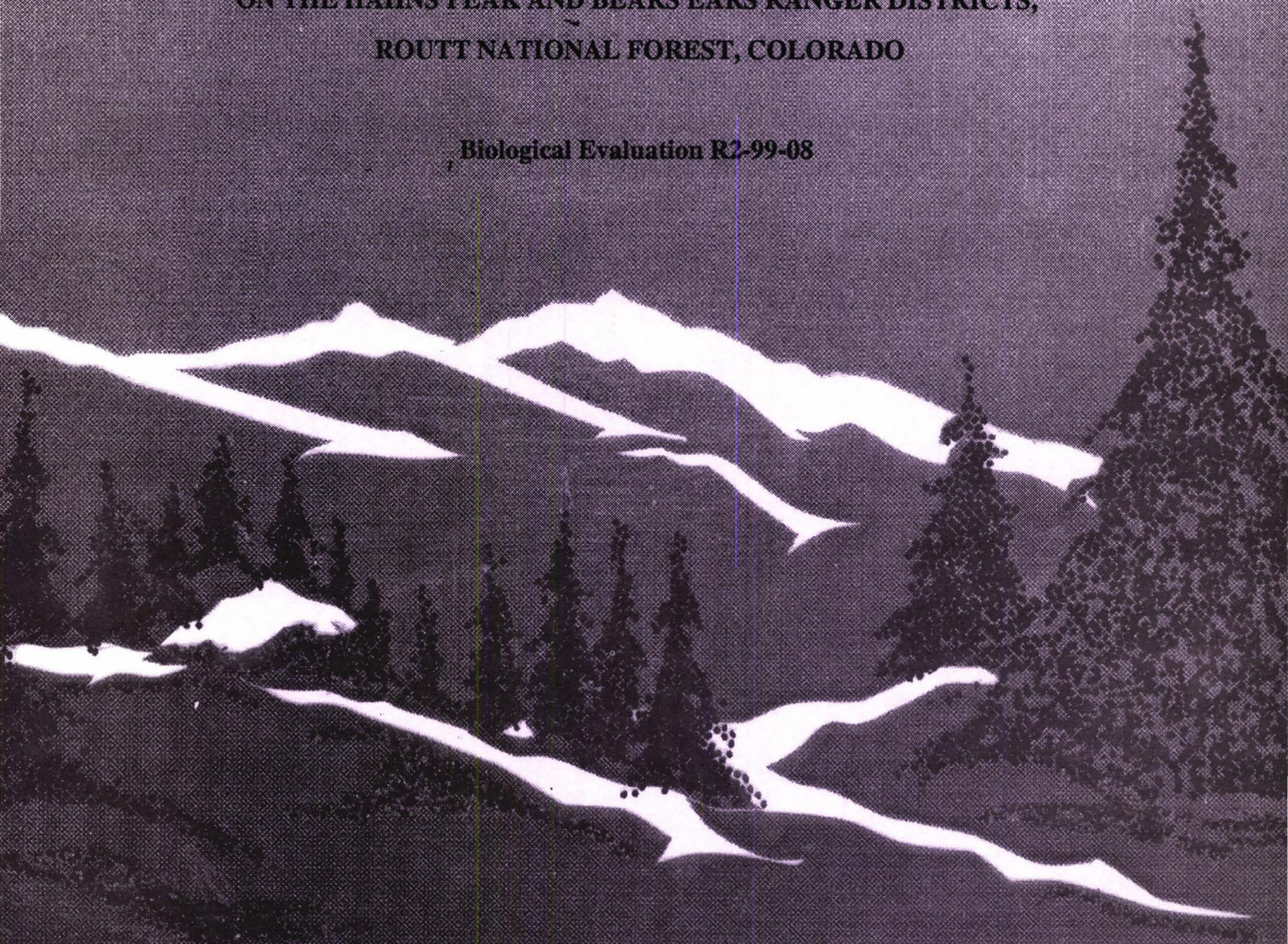
Forest Health Management

EVALUATION OF THE SPRUCE BEETLE IN 1998 WITHIN THE ROUTT DIVIDE BLOWDOWN OF OCTOBER 1997, ON THE HAHNS PEAK AND BEARS EARS RANGER DISTRICTS, ROUTT NATIONAL FOREST, COLORADO

Biological Evaluation R2-99-08



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Biological Evaluation R2-99-08

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SUMMARY

The wind event which caused the Routt Divide Blowdown (RDB) has resulted in abundant spruce beetle breeding material throughout the spruce/fir forest vegetation type on the Hahns Peak/Bears Ears Ranger District (HPBE) of the Routt National Forest. This material is readily available to populations of spruce beetle and will remain suitable for several years. During the 1998 field season, spruce beetle was just beginning to infest the downed spruce trees. Sparse populations were found at most survey locations, indicating that spruce beetle is widely distributed. A small percentage of the spruce beetle population within the windthrow was determined to be on a one year life cycle, which will either reinfest downed trees or attack standing weakened trees in the summer of 1999. Additional infestation of the RDB is expected in 1999. The current condition of many of the spruce stands on the HPBE, with continued windthrow and standing damaged trees, will create more potential host material for beetle populations for 2 to 5 more years, depending on climatic conditions. It is likely that the spruce beetle population will increase within this windthrow and eventually will move into the nearby forest, killing green spruce trees. The extent, intensity, and duration of such an event can not be predicted at present. It is possible that the scale of this predicted event will cover several landscapes and result in significant spruce mortality and associated impacts. Actions to mitigate spruce beetle impacts are described and recommendations made. It must be stated plainly that once a landscape-level spruce beetle epidemic commences, there are no known management actions that can bring it to a halt, that do not include major landscape level activities.

ACKNOWLEDGMENTS

Grateful appreciation is extended to the many employees from the Routt National Forest and the Forest Health Management group who worked on this project, whether in the forest or the office.

INTRODUCTION

Several major episodes of windthrow occurred on the Medicine Bow/Routt National Forests (MBR) in 1996 and 1997 have resulted in an unusually large acreage of blowdown, predominantly in the spruce/fir forest cover type.

The focus of this evaluation is the largest of these windthrow events, referred to as the "Routt Divide Blowdown" (Figure 1). Early on the morning of October 25, 1997, winds estimated to be in excess of 120 m.p.h. uprooted a large number of trees on the MBR. Approximately 13,000 acres of blowdown has been mapped in Colorado, primarily on the west side of the Continental Divide in the Sierra Madre and Gore mountain ranges north of US Highway 40. Most of the affected land is publicly owned and is administered by the HPBE. Approximately 8,000 acres of the RDB is within the Mt. Zirkel Wilderness Area. Many of the windthrown trees from this wind event maintained root contact. Additional blowdown is continuing to occur and smaller areas of blowdown not previously mapped are being identified. The total area with some blowdown is probably several times greater than the reported acreage. Two other blowdowns are mentioned in this evaluation. The Cyclone Blowdown which occurred on September, 1996, in the Dunckley Pass area of the Yampa Ranger District, Routt National Forest.

This area is approximately 30 miles southwest of Steamboat Springs. The Cyclone Blowdown covered about 400 acres in several long, narrow strips. The blowdown at Walton Creek occurred in September 1997, a month prior to the RDB. This blowdown is located approximately 11 miles southeast of Steamboat Springs and at the southern extent of the RDB. The blowdown at Walton Creek covered one patch of about 3 acres.

The spruce beetle, *Dendroctonus rufipennis* [Kirby] (Order Coleoptera; Family Scolytidae), is the principle forest insect of concern in these blowdown areas. Normally this native beetle is present in small numbers in weakened or windthrown trees, large pieces of logging slash, and fresh stumps. Individual or small, scattered groups of standing trees may be killed, creating snags and gaps in the forest canopy. Natural enemies, weather, competition, and other factors combine to keep beetle populations at low levels. Sporadic spruce beetle outbreaks have killed extensive areeas of spruce in parts of western North America, including Alaska, western Canada, Colorado, Montana, Arizona and Utah. Such outbreaks commonly develop in windthrown timber. Spruce beetle populations can increase dramatically within windthrow, from which they emerge to attack and kill standing, living trees. Like fire and wind, the spruce beetle is a natural, though destructive, means for liquidating overmature forests and making way for the new forests (Furniss and Carolin 1977). The spruce beetle is the principle biotic agent that can create massive landscape level disturbances in the spruce forests of western North America.

Since the 1800s, several landscape level spruce beetle outbreaks have occurred in Colorado (Table 1). These outbreaks have affected large geographic areas. The best documented spruce beetle outbreak in Colorado originated from a blowdown event which occurred on June 20, 1939, in the Flat Tops area of the White River National Forest. The outbreak was discovered in the summer of 1942 and over the next 12 years, various efforts were made to deal with the outbreak. These included salvage of blown down trees, removal of standing infested trees, using trap trees, and direct chemical control (Nelson 1950). Standing dead trees from this outbreak were still being salvaged on the White River National Forest in 1998.

Table 1. Recorded landscape level spruce beetle outbreak locations and dates with estimated volume losses in Colorado since 1850.

General Outbreak Location	Estimated Date of Outbreaks	Estimated mortality
Pike National Forest	1855	Unknown
White River National Forest	1870s through 1890s	10 to 25% of mature spruce
Grand Mesa National Forest	1870s through 1890s	25 to 40% of mature spruce
White River National Forest	1939 through 1954	3.5 billion board feet
Grand Mesa National Forest	1939 through 1954	35-50 million board feet
Routt National Forest	1939 through 1954	74 million board feet
Uncompahgre National Forest	1939 through 1954	5 million board feet
Arapaho National Forest	1939 through 1954	29.5 million board feet
Gunnison National Forest	1939 through 1954	Unknown lesser amounts
San Juan National Forest	1939 through 1954	Unknown lesser amounts
Wolf Creek Pass	1970s	Smaller outbreaks, killing hundreds of spruce trees
San Juan National Forest	1970s	
Gunnison National Forest	1970s	

Spruce beetle life cycle and habits differ widely in various portions of this vast range. Developing immature spruce beetles, called "larvae," feed on the phloem or inner bark of all species of spruce. Spruce beetle prefers shaded, downed spruce trees as host material in which to reproduce. In general, this beetle has a two year life cycle in Colorado, where it reproduces primarily in Engelmann spruce (*Picea engelmanni* Parry) and, to a lesser degree, in blue spruce (*P. pungens* Engelmann). Adult beetles can fly as soon as the snow melts away from the base of trees in the spring. In the 2-year life cycle, trees are attacked and eggs are laid under the bark in late June and early July. Most eggs hatch, and the larvae begin to develop by August to mid-October of that same year. In this first year of the life cycle, it is the larvae that overwinter. The next season the larvae complete their development, pupate, and transform into adult beetles. The second winter of the life cycle is spent in the adult stage. New adult spruce beetles that developed inside standing trees may emerge from their host tree and relocate inside the base of the tree trunk or root collar to hibernate through their second winter. In contrast, new adult spruce beetles that developed inside blowdown will stay and overwinter in the same log where they developed. The following spring, two years after eggs were first laid, the mature spruce beetles will reinfest a different portion of the same blowndown log or move to an adjacent log and begin the next generation of the life cycle by mating and depositing eggs. In the absence of suitable blowdown, spruce beetle will attack and attempt to colonize standing trees. Under certain conditions spruce beetles may complete their life cycle in one year. The percentage of spruce beetles exhibiting a one year life cycle is usually small.

Several actions have been taken by Forest Health Management staff to monitor and evaluate spruce beetle populations on the Hahns Peak/Bears Ears Ranger Districts. These include aerial surveys to detect recent tree mortality and blowdown, monitoring beetle flight by deploying spruce beetle pheromone traps, conducting a spruce beetle infestation extent survey, and conducting spruce beetle brood sampling to determine the density and predominant life stages of spruce beetle present in the blowdown.

METHODS

Aerial Survey

Aerial surveys were conducted from fixed wing, single engine aircraft flying at about 1,500 feet above the ground at approximately 100 miles per hour. When the observer detected recent tree mortality, the number of dead trees and probable cause(s) of death were coded, and the affected area sketched onto 1:100,00 scale US Geological Survey 30 X 60 minute maps. In the case of tree mortality from bark beetles, recent activity was detected as faded tree crowns. For spruce attacked by spruce beetle, the color of the faded tree crown would be a pale greenish yellow. A clumped spatial pattern of faded trees and adjacent grey snags could serve as additional clues. Similarly, windthrow areas were detected and estimated as polygons sketched onto the maps. Missions were flown during the "biological window" for bark beetles, the time of year that conifers fading from bark beetle colonization can best be detected.

Pheromone Trapping

The spruce beetle adult flight and attack period was monitored using traps baited with a chemical attractant. Trap capture data was intended to establish the presence of attacking spruce beetles in an area and to determine the timing of such attacks. Traps must be deployed prior to spruce beetle emergence in

the spring and be checked regularly. The bait used in these traps takes advantage of the spruce beetles' own chemical communication system.

Spruce beetles tunneling into a tree emit airborne chemicals that are highly attractive, stimulating nearby beetles to aggregate on the tree under attack. This chemical communication system serves to focus and to coordinate attack and colonization of trees. Such message-bearing chemicals are called "pheromones," which operate at remarkably low airborne concentrations in a species-specific, non-toxic manner. The traps are a vertical array of 16 interlocked black funnels that simulate the silhouette of a tree trunk, with a capture container at the base of the funnels. This "Lindgren" trap type was specifically developed for tree-killing bark beetles and is widely used in forest entomology.

Lindgren funnel traps baited with synthetic spruce beetle aggregation pheromone were deployed to monitor beetle flight in 1998. Two traps per location were deployed at seven locations, six spanning the RDB area and one on Dunckley Pass in the Cyclone Blowdown of September, 1996. In 1998, spruce beetle traps were deployed on the following dates: May 18, 19 and 20 and June 1. The traps were checked and emptied approximately weekly.

Extent Survey

The extent of spruce beetle infestation in windthrow was surveyed by both Forest Health Management and Routt National Forest staff. The Routt National Forest staff were trained in the field during the week of September 14, 1998, by Forest Health Management staff to help accomplish this survey, with additional assistance provided as needed. Data were recorded on sheets specifically designed for the project.

Patches of known windthrow and patches of windthrow identified by aerial survey or aerial photography were candidates to be surveyed. At each patch visited, the blowdown acreage to be examined was estimated. A total of 10 spruce trees per patch was established as the desired minimum sample size. For blowdown patches of 10 or more acres, one additional tree was to be added to the minimum sample, up to a maximum of 100 trees per patch. In cases of scattered, isolated blowdown, field crews examined as many fresh windthrown spruce as they could locate. An attempt was made to distribute examined trees evenly around the perimeter of a blowdown patch. Individual windthrown spruce were surveyed for the presence of spruce beetle by chopping into the tree and examining the phloem in at least three separate spots along the trunk where the diameter was 10 inches or more. A visual search for external signs of infestation was performed along the entire tree while moving between spots where chopping was done. It was stressed that visual examination alone was not sufficient to establish the presence or absence of spruce beetles. The well known preference of spruce beetle for shaded, cooler, often less accessible locations on logs was made clear. Once spruce beetle infestation was confirmed in a tree by identifying galleries or insects, the examiner moved along to another tree. Information on the presence of *Ips* beetles, the relative density of *Ips* beetle galleries, spruce beetle life stages encountered, and the relative moisture level of the phloem, as well as any additional comments, were noted on the data sheets.

Brood Sampling

Brood sampling of spruce beetle populations was conducted according to the 'Biological Evaluation Procedures' section of Schmid (1981, page 4). One set of 6 inch by 6 inch bark samples was cut from anywhere along the infested portion of each windthrown sample tree, excluding 5 feet at each end. A

sample set consisted of one 6 inch by 6 inch bark section cut from the top, lateral, and bottom surface of each sample tree. Each bark section was carefully removed with a chisel or hatchet so that the phloem and any insect within it was unharmed. Samples were placed individually in a labelled plastic bag and kept cool or refrigerated until they were dissected in the laboratory at the Lakewood Service Center. Data sheets were used to collect information from each sample on the number of spruce beetles by life stage, the number of attacks, the number and length of galleries, and information on associated organisms such as *Ips* beetles and natural enemies. The infested length and diameter at the midpoint of the infested length was recorded for each sample tree. A numbered, round metal tag was nailed to the base of each sampled tree, which was also marked with red and white striped flagging, and a rough map of sample trees made to allow relocation and resampling in 1999. Neither the total number or diameter at infestation midpoint of all infested trees per windthrow patch nor the average diameter at breast height of the surrounding, standing trees was estimated, contrary to the biological evaluation procedures described by Schmid (1981).

RESULTS AND CONCLUSIONS

Aerial Surveys

Aerial survey missions from 1996 - 1998 detected very little recent spruce mortality attributed to spruce beetle. From these survey missions, we concluded that spruce beetle activity was at low levels over a large area, which includes the RDB, from 1994 or 1995 through 1998. Details of these aerial survey missions follow.

Forest Health Management staff, assisted by Timothy McConnell (Aerial Survey Program Manager, USDA Forest Service - Northern Region, Forest Health Protection, Missoula Field Office) conducted aerial surveys of the entire Routt National Forest and environs, including the Park and Gore ranges, Medicine Bow mountains, and Flat Tops, on October 1 - 4 and 8 - 9, 1996. No recent spruce mortality was detected in the area covered by these surveys. The only spruce mortality attributed to spruce beetle during any of these missions was a scattered total of 28 trees in 9 spots on the central and southern Flat Tops, located more than 30 miles west and southwest of Oak Creek.

On August 6 - 8, 1997, an aerial survey of the Sierra Madre and Medicine Bow mountain ranges, including the Medicine Bow National Forest and environs, was conducted by Forest Health Management staff. In the southeastern portion of the Sierra Madre Mountains, on and near Bear Mountain, and east of the Encampment River, seven polygons totalling 868 recently killed spruce were coded onto the sketch maps by the two observers. Each of these areas was ground checked for accuracy of the flight and found that, in actuality, no spruce beetle activity was evident.

The RDB occurred on October 25, 1997 and the initial aerial reconnaisance flights of the blowdown were conducted on October 29, 1997. This flight mapped the extent of the RDB, and provided the first estimates of the acreage involved. A subsequent aerial photography flight refined the locations of blowdown as well as the acreage estimates.

On August 12, 13, and 18 - 21, 1998 Forest Health Managment staff surveyed the entire Routt National Forest and environs, including the Gore and Park Range(s), the Medicine Bow Mountains, and Flat Tops.

One polygon of 5 recently killed trees was attributed to spruce beetle, located between Smith and Solomon Creeks adjacent to USFS Road 129 about 7 miles north of Steamboat Lake and a second, similar polygon was placed on the west side of the Elk River at Mad Creek about 7 miles northwest of Steamboat Springs, visible from USFS Road 129. These were the only two spruce beetle polygons coded in the areas surveyed, excluding the Flat Tops.

Pheromone Trapping

Lindgren funnel traps baited with synthetic spruce beetle aggregation pheromone were deployed in both the RDB and the Cyclone Blowdown on Dunckley Pass. Six sites were trapped in and near the RDB, with location names as follows: Lost Dog, Three Island Creek, Floyd Peak, Mad Creek, Buffalo Pass, and Walton Creek. This last site was the only one to capture spruce beetles during the 1998 field season. The Walton Creek trap site captured a single beetle the week of July 6 and another single beetle the week of July 13. The traps in the Cyclone Blowdown on Dunckley Pass also captured single beetles during each of the following weeks: June 5 and August 7.

Extent Survey

The extent survey for spruce beetle infestation in windthrow showed that spruce beetle was more generally distributed across the blowdown areas than was expected (Figure 1). As Table 2 shows, spruce beetle infestation was found at 30 of the 35 sites checked, comprising 86% of these sites.

The distribution of spruce beetles at these extent survey sites was patchy both among sites and within trees inspected at a given site. A total of 364 blown down trees were checked for spruce beetles, and of these, 168 (46%) had some level of spruce beetle infestation (Table 2). The percentage of infested windthrow varied a great deal among sites. With the exception of the site at the Cyclone Blowdown (T3-R87-S27 in Table 2), it seemed that most of the infested windthrow was not fully occupied by either spruce beetle or *Ips*.

During the extent survey and general recognizance activities, spruce beetle pupae and "callow" or new adults were found within windthrow from the RDB. This was unexpected, because it is the larval stage that spans the first winter of a 2-year spruce beetle life cycle. This finding of pupae and new adults indicated that a portion of the spruce beetle population completed its life cycle in one year. Due to the difficulty of distinguishing new from parent adult beetles, however, it cannot be assumed that "callow" or new adults were found at all extent survey sites which had live adult spruce beetles present (Table 2, right column). One year spruce beetles were confirmed at the following areas: Walton Creek (T5N-R83W-S24), the Steamboat Springs Ski Area (T6N-R83W-S32), Floyd Peak (T9N-R84W-S34), Seedhouse Campground (T10N-R84W-S02), and the Slavonia Trailhead (T10N-R83W-S04). It should be noted that several of these sites are just above 10,000 feet in elevation. All of these areas are extent survey sampling sites, listed in Table 2. It is likely that there are more areas where spruce beetles developed in one year in blowdown.

Table 2. Extent survey data from the Routt Divide Blowdown and vicinity to detect spruce beetle infestations in windthrow, conducted in September and October, 1998. Note that "SB" abbreviates "spruce beetle" below.

Township (North)	Range (West)	Section	Number of Trees Examined	Number of Trees with SB	Percent of Trees with SB	SB Pupae Present?	Live SB Adults Present?
3	87	27	16	11	69%	N	Y
5	83	24	28	13	46%	N	Y
5	83	14	5	4	80%	N	Y
5	83	3	2	2	100%	Y	Y
5	83	17	4	4	100%	Y	Y
5	83	10	10	6	60%	Y	Y
5	83	17	11	6	55%	N	Y
6	83	29	3	0	0%	N	N
6	83	27	10	2	20%	Y	Y
6	83	28	10	3	30%	Y	Y
6	83	4	10	2	20%	Y	N
6	83	29	10	0	0%	N	N
6	83	5	10	2	20%	Y	Y
6	83	29	9	5	56%	N	Y
6	83	32	10	9	90%	Y	Y
6	84	1	10	5	50%	Y	Y
6	84	1	10	2	20%	Y	Y
9	84	34	15	9	60%	N	N
9	84	11	13	8	62%	N	Y
9	84	34	24	20	83%	N	Y
9	89	13	5	5	100%	Y	Y
10	83	34	10	0	0%	N	N
10	83	4	10	0	0%	N	N
10	83	4	32	11	34%	Y	Y
10	83	34	10	1	10%	Y	Y
10	83	4	10	0	0%	N	N
10	83	1	10	1	10%	Y	N
10	84	2	20	18	90%	Y	Y
10	86	19	4	3	75%	Y	Y
10	87	23	3	2	67%	Y	Y
10	89	5	5	4	80%	Y	Y
11	85	2	11	3	27%	Y	Y
11	85	3	3	3	100%	Y	Y
11	86	33	2	1	50%	Y	N
12	85	20	9	3	33%	Y	N
35 sites		TOTALS	364	168	46%		

Brood Sampling

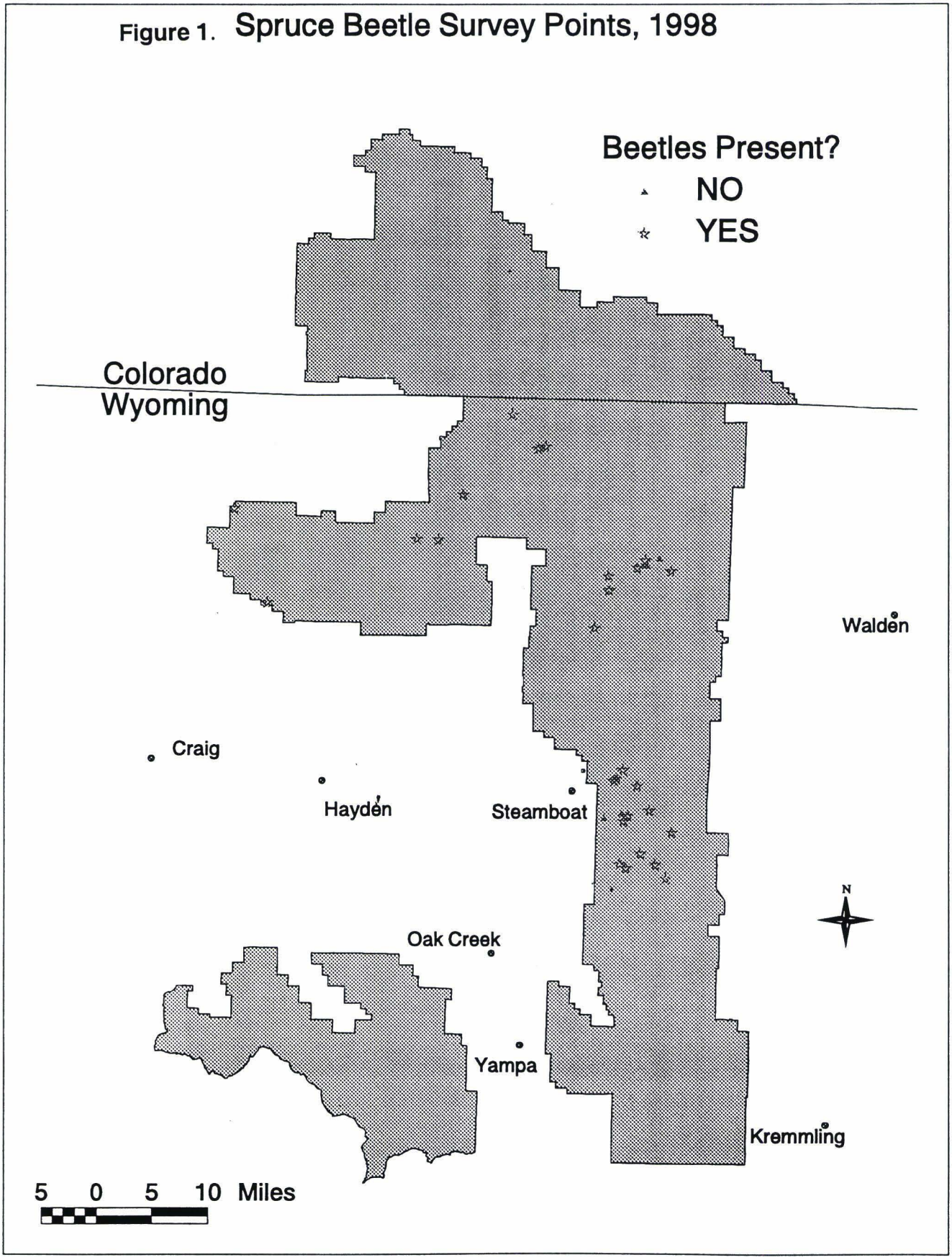
Using the biological evaluation technique developed by Schmid (1981), it was determined at two sites that attack and brood densities of spruce beetle within windthrow were very low in 1998 (Table 3). Only two sites were sampled using this technique, the blowdown at Walton Creek and a part of the RDB just west of Buffalo Pass (Figure 1). In both cases, the variation between samples was large, as indicated by the standard deviation of the means. Most samples were zero, despite our efforts to select infested windthrow to sample. At Walton Creek, half of the trees selected for sampling had no spruce beetle life stages in any of the three samples. At Buffalo Pass, 20% had no spruce beetle life stages in any of the three samples. The greater proportion of samples containing spruce beetles at Buffalo Pass was also reflected in the higher attack and brood densities at that site. Because the blowdown was first attacked in 1998, these brood estimates reflect attack densities without the confounding influence of brood mortality. The attack densities are therefore an indication of the size of the resident population at these two sites that was available to infest the windthrow. In both cases, our findings indicate a small resident spruce beetle population.

These limited results parallel those of Schmid (1981) with respect to the pattern of attack and brood densities. Schmid (1981) states that attack densities of 3 or less per square foot on the bottom surface were associated with non-outbreak populations of spruce beetle. Although our results are well below that threshold, it is premature to conclude much from this baseline information. We expect additional attacks in 1999, and look to future brood sampling to provide an indication of where spruce beetle populations may grow to outbreak proportions.

Table 3. Mean attack and brood densities per square foot of bark surface for the spruce beetle, *Dendroctonus rufipennis,* from 10 windthrown spruce per site at two sites in the Gore Range, Routt National Forest, as estimated from one 6 inch by 6 inch bark sample taken from each of three surfaces on each sample tree. (Numbers in parenthesis are standard deviations of the means.)

VARIABLE	LOCATION	
	Buffalo Pass	Walton Creek
% samples with SB present	20 %	40 %
Mean attack density (Bottom)	1.6 (0.9)	0.4 (0.4)
Mean brood density - Top	11.2 (10.8)	0.0 (0)
Mean brood density - Side	5.6 (3.4)	1.6 (1.6)
Mean brood density - Bottom	35.6 (14.2)	14.0 (29.8)

Figure 1. Spruce Beetle Survey Points, 1998



DISCUSSION

Aerial Survey

Information obtained from aerial survey is inherently subject to error due to the conditions under which observations are made. Aerial surveys are a rapid, relatively inexpensive means to detect forest insect and tree disease activity over large geographic areas. It is possible that some spruce beetle activity was not detected, as it is among the most difficult "pest signatures" to discern during aerial survey. It is highly unlikely, however, that if significant spruce beetle activity occurs, it would go undetected. The conclusion that no spruce beetle epidemics were underway in the vicinity of and prior to the RDB is warranted. This conclusion is reinforced by negative findings on the ground by Forest Health Management staff and no reports from the field by MBR staffs. Spruce beetle populations were at endemic or low levels when the RDB occurred.

Pheromone Trapping

Natural infestations are known to be more attractive to spruce beetle than baited Lindgren traps. The most likely explanation for negative trapping results is that the traps could not compete with infested windthrow in attracting flying spruce beetles. The Lost Dog site is the only pheromone trap site not within the spruce/fir cover type, being several miles distant. It may be that there were no spruce beetles in that vicinity. The Walton Creek site is at the southern extent of any blowdown on the Gore Range and windthrow is scarce in the vicinity. This blowdown patch is over one-half mile distant from these two traps, which did capture two spruce beetles. The windthrown spruce at the Dunckley Pass site from the Cyclone Blowdown has dried out and is no longer suitable for infestation by spruce beetle or *Ips*. The few spruce that have fallen at the Dunckley Pass site since the Cyclone Blowdown are the most densely infested windthrow we have observed to date. This concentrated spruce beetle infestation suggests that a reduced amount of acceptable host material is present at this site, the second of two sites where pheromone traps captured spruce beetles. Events on Dunckley Pass may foreshadow future events in and around the RDB.

It may be that the pheromone traps will not begin to capture significant numbers of spruce beetles in a given location until there is a reduction in available, attractive windthrow. As such, these pheromone traps may be an "inverse indicator," capturing spruce beetles when the "competition" from fresh windthrow has been reduced, when spruce beetle populations are having to search extensively for host material. Increases in pheromone trap catches may be expected when the spruce beetle population is moving out of the windthrow, and begins to attack standing spruce.

The absolute numbers of beetles captured by pheromone traps cannot be interpreted other than to demonstrate spruce beetle presence in the vicinity and the approximate timing of flight. However, by comparing capture data at the same site in successive years, one can make inferences about the relative spruce beetle population size. Because they capture flying beetles from the air, each trap is capable of sampling a larger area than could be assayed by looking at individual trees. Currently, the spruce beetle pheromone trapping sites within the RDB have not been used for a long enough period of time to make inferences from catches.

Extent Survey

The extent survey for spruce beetle infestation in windthrow was conducted to determine if there were areas of blowdown which were attacked by spruce beetle during the 1998 field season. It was expected that spruce beetle might be found in only a few locations that could then be monitored and managed intensively. This expectation was fostered by the general absence of any recent mortality attributed to spruce beetle in standing trees as determined from aerial surveys, by a lack of reports from the field of active spruce beetle populations, and by the assumption that endemic or low level populations would not be widely distributed. The widespread distribution of spruce beetle in windthrow that was discovered at the sites we surveyed counters our expectations and eliminates the possibility of dealing with a few, isolated populations that could be intensively managed. The potential problem presented by spruce beetle inhabiting windthrow exists in many places.

During the extent survey it was discovered that a small number of spruce beetles had gone through their life cycle in one season. These "callow" or new adults were found in windthrow from the October 25, 1997, blowdown. An alternative explanation to a one year life cycle is that these new adult beetles actually took two years to develop inside host trees in 1996 while still standing, and that these standing, infested trees were blown over in 1997, wherein the beetles completed their development. In all the windthrow we examined with one year or new adults, evidence of spruce beetles was found mainly on the bottom surface and occasionally on side surfaces, and almost never on the top surface. Had these trees become infested while standing, we would expect that most trees would have had spruce beetles distributed somewhat evenly around the entire tree stem. The restricted infestation pattern we observed, however, is characteristic of unshaded windthrow infested by spruce beetle. A one year life cycle in windthrow has been documented (Safranyik and Linton 1999 and references therein).

The one year spruce beetles do add a note of urgency when dealing with the spruce beetle issue. These insects will emerge in the summer of 1999 and infest additional blowdown material if available. If additional blowdown material is not available, these individuals will attack standing trees. Either way, one year spruce beetles have the potential to increase the spruce beetle population at a more rapid rate even though they are a small percentage of the population at this time.

Brood Sampling

Schmid's biological evaluation procedures (Schmid 1981), if followed completely, allow calculation of the potential number of infested standing trees that could result, two years into the future, from the spruce beetle brood that is being sampled in the windthrow patch nearby. This predictive calculation was not attempted in 1998. Casual observations and results from the extensive sampling indicated that spruce beetle densities in windthrow from the RDB would be very low in 1998. Because 1998 was the first year that the windthrow could be infested, it is expected that additional colonization of these windthrown trees will occur in 1999. Due to the low brood densities and expected additional attacks, it was decided to postpone collecting the necessary data for the calculation of potentially infested, standing trees until 1999, at least. Because spruce beetle usually has a two year life cycle, the number of resident adult beetles that emerge and can attack windthrow or standing trees may be very different from year to year. Schmid's calculation method may be most appropriate for blowdown patches that are small enough to be examined completely, as the total number and diameters at infestation midpoint of infested trees per patch must be tallied in order to make the calculation.

The wind event which caused the RDB has resulted in abundant spruce beetle breeding material throughout the spruce-fir forest vegetation type on the Forest. This material is readily available to populations of spruce beetle and will remain suitable for several years. During the 1998 field season, spruce beetle was just beginning to infest the downed spruce trees and sparse populations could be found in almost any patch of blowdown. There are also a small number of spruce beetles on a one year life cyle that will either reinfest downed trees or attack standing weakened trees in the summer of 1999. The current condition of many of the spruce stands on the HPBE, with continued windthrow and standing damaged trees, will create more potential host material for beetle populations for 2 to 5 more years, depending on climatic conditions.

Spruce beetles in windthrown trees are afforded some protection from mortality agents such as weather extremes and predators. The weather conditions for the winter of '98-'99 were not severe enough to cause significant mortality to overwintering spruce beetle populations. Therefore, we can expect a large percentage of the spruce beetle population currently in windthrown trees to survive and continue to develop.

Based on past experience with significant windthrow events, it is expected that the spruce beetle population will increase within the windthrow for several years and then move into the surrounding forest, where they will attack and kill standing spruce trees. The location(s), extent, and duration of this predicted spruce beetle epidemic is not known. The immensity of the RDB, the wide variety of blowdown patch sizes and the different conditions in these patches present the spruce beetle with a very significant opportunity. With a susceptible spruce/fir forest and favorable weather, the spruce beetle most likely will create landscape level disturbances, liquidating the mature spruce component of forested areas. Management efforts can have local effects that will mitigate spruce beetle impacts to varying degrees, and shape how the next forest looks. We know of no way to stop a landscape-level spruce beetle epidemic once it has reached a size where it is beyond our capability to respond.

RECOMMENDATIONS

1. Develop a worst-case scenario. Determine and depict, based on forest condition, what an intense spruce beetle epidemic may do. Published information is available that, using stand inventory or other forest inventory data, allows classification of stand conditions with respect to estimated spruce mortality, given a spruce beetle epidemic. This is commonly called "risk-rating" (Schmid and Frye 1976). It is automatically calculated by the USDA Forest Service's Rocky Mountain Resource Information System where stage II stand inventory has been collected and entered into the database. It appears in the field called "bug_risk." Such an assessment will allow land managers to identify key resources and areas that will be significantly and negatively impacted by a worst case spruce beetle scenario.

2. Take a stand against the worst case scenario. Determine if there is an opportunity to use silvicultural methods to alter the forest conditions so that they are less favorable to spruce beetle before an epidemic develops. The larger, more isolated, and more ecologically unified an area that is treated, the greater the chance of success. While there is limited published research that confirms the role of thinning in reducing potential mortality from spruce beetle, research on related tree-killing bark beetles strongly implies that such activities may mitigate spruce beetle impacts. This is a unique opportunity to develop needed

information while simultaneously attempting to provide an area with some protection. Therefore, a demonstration thinning project for spruce beetle prevention should be implemented to take advantage of the current situation.

3. The salvage or removal of as much blowdown material as practical will reduce the host reservoir for the spruce beetle. Such trees may act as trap trees whose removal will prevent reinfestation as well as beetle maturation and flight to new trees. This may help reduce the incidence of green standing attacks in certain areas.

4. In areas where timber salvage activities occur, take site specific measures to provide additional monitoring and mitigation. This should include the creation and treatment of trap trees in accordance with contract specifications. The deployment of additional pheromone traps to monitor subsequent spruce beetle behavior should be considered.

5. In ecologically sensitive areas, other types of treatments might be considered that would make downed spruce unsuitable for breeding material or would kill the current population of beetles infesting logs. This might include peeling or barking the logs in some way and/or burning to denature the phloem.

6. Continue to implement adaptive forest managment, to survey, evaluate, and monitor spruce beetle populations. Knowledge of the beetle population, when combined with an assessment of forest susceptibility, will allow the most accurate forecasting of what will happen that can be accomplished.

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